UCRL-JC-126268 Abs

Aligned Wafer Bonding for Microfluidic Devices

James A. Folta
Conrad Yu
William J. Benett
Dino Ciarlo
Lawrence Livermore National Laboratory
L-222, PO Box 808, Livermore, CA 94551

We have developed a variety of techniques to perform aligned bonding of both silicon-to-silicon and silicon-to-glass wafers. Aligned wafer bonding is a key technology in our development of microfabricated components for microflow systems. Examples include microvalves, microcapillaries for gas chromatography and electrophoresis, and microchannel heatsinks for cooling high average power laser diode arrays. We describe and compare five different alignment techniques: alignment pins inserted through holes; alignment pins inserted into etched grooves; mechanical alignment to flats cut with a precision dicing saw; alignment with a commercial precision wafer aligner/bonder; and manual hand alignment of glass to silicon. Table 1 compares the merits of the 5 aligned bonding techniques.

(1) Alignment pins inserted through etched or drilled holes—The microchannel heatsinks consist of a 3 wafer silicon-glass-silicon stack. The 3-wafer stack was anodically bonded in 1 step in which a pair of 6 mm diameter pins were inserted through sets of alignment holes. The (110) silicon orientation allowed anisotropic etching of vertical-walled alignment holes with precision size control. The holes in the glass were ultrasonically drilled.

(2) Alignment pins inserted into etched grooves—Two sets of shallow grooves etched into the wafer surfaces were aligned to one another with pins which are slightly oversized to prevent contact of the wafer surfaces. After deflecting the wafer centers into contact, the pins were removed. Alignment accuracy is strongly dependent on the accuracy of etching the alignment grooves. For V-grooves etched in (100) silicon, the groove width, location, and rotation require careful alignment to the crystal during photolithography. Figure 1 shows an SEM cross section of a GC separation capillary fabricated with this technique.

(3) Mechanical alignment to flats cut with a precision dicing saw—A diamond saw can be used to cut sets of alignment flats into the wafers which can be aligned to either flats or pins in an alignment fixture. Thin tabs inserted between the wafers prevent premature contact during alignment for silicon-to-silicon bonding.

(4) Alignment with a commercial precision wafer aligner/bonder—An Electronic Visions AL6-2 double-sided aligner/wafer bonder was used for aligned wafer bonding. The bonder utilizes alignment marks patterned onto the wafers in much the same way that alignment marks are used for photolithographic mask alignment. The bonder maintains a gap between the wafers during alignment, bulges one wafer during contact so that initial contact occurs at the wafer centers, and then applies vacuum to the contacted pair to promote intimate contact. Care must be taken to insure that the wafer pairs are compatible with the bonding hardware: examples include location of alignment marks, one set of which is on the backside of a wafer, and the fact that the wafer perimeters must be clear to allow holding with a vacuum chuck. The bonder does not utilize infrared transmission imaging, so that single side polished and metallized wafers are readily aligned.

(5) Manual hand alignment of glass to silicon—For anodic bonding of glass to silicon, the transparency of the glass can be used to advantage. A low power magnifier or microscope can be used to view alignment marks while the wafers are being aligned. Unlike silicon-to-silicon bonding in which alignment must be performed prior to contacting the surfaces, the glass and silicon can come into contact be allowed to slide during alignment. Mechanical clamping was used to secure the position during bonding.

*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

Table 1: Comparison of Aligned Bonding Techniques

Method		Merits
1		±15 μm accuracy
	+	low cost, fast
	+	multiple wafers simultaneuosly
	+	production volumes demonstrated
	-	sharp edge on holes in (100) problematic
2		±5 μm accuracy??
		depends on groove etch accuracy
	+	low cost
3		±15 μm accuracy??
	+	low cost
	-	requires extra dicing steps + cleanup
4	+	±2 μm accuracy
	-	expensive equipment
	-	need backside alignment marks
5	-	±50 μm accuracy, operator dependent
	+	low cost
	-	one wafer must be transparent

Figure 1: SEM of 100 μm GC capillaries of circular cross section formed by bonding 2 wafers with etched semicircular channels.